

Soldier Representation in Modeling and Simulation



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14. ABSTRACT This multi-year project had 3 primary objectives: 1) to leverage Naval Postgraduate School (NPS) student and faculty research to improve the modeling of the individual Soldier and small units; 2) to provide support to the Soldier Focus Area Collective Team (FACT); and 3) to develop centralized lines of communication between consumers and developers of infantry (individual combatant) models, simulation, and data. We successfully drew numerous NPS students and faculty into Soldier M&S-related topics and, as a result, successfully increased the visibility of Soldier M&S at NPS, leading to a great number of Soldier M&S advancements. Additionally, we developed a prototype collaborative web portal to facilitate communication between Soldier M&S researchers, developers and consumers. This report summarizes the numerous student, faculty, and internal efforts to address Soldier M&S issues; our role in the Soldier FACT; and the development of the prototype web portal.					
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There were many others besides the team members mentioned above that contributed to the project through their advice and recommendations. Their names are too numerous to mention here, but come primarily from the following organizations: the US Army Training and Doctrine Command (TRADOC) Analysis Center (TRAC) at White Sands Missile Range (TRAC-WSMR), the US Army Materiel Systems Analysis Activity (AMSAA), Dismounted Infantry Team, the US Army Natick Soldier Center, Modeling and Analysis Team, numerous directorates within the US Army Infantry School (USAIS) and Center (USAIC), and the TRAC Methods and Research Office (TRAC MRO).

Without the untiring efforts and expertise of the above individuals and organizations, this significant effort would not have been successful.

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Executive Summary

We initiated this multi-year project in March, 2004, and continued our research through October, 2007. The primary objectives of this project were three-fold: 1) to leverage student thesis and dissertation work, as well as professor research, at the Naval Postgraduate School (NPS), in order to improve the modeling and simulation (M&S) community's ability to model the individual Soldier and small units; 2) to be a member of, and participate actively in, the Soldier Focus Area Collaborative Team (FACT) process as an Executive Committee (EXCOM) member; and 3) to develop centralized lines of communication between consumers and developers of infantry (individual combatant) models, simulation, and data by providing a means to summarize current research efforts, challenges, and requests for information in a manner accessible to all stakeholders.

We were very successful in getting the support of numerous students and faculty during the conduct of this three-and-half-year effort. In fact, during this timeframe, we attracted or shared the research of 24 students in two NPS Departments, at least seven NPS Ph.D. faculty members, 12 theses and dissertations for which TRAC-MTRY served as second readers or dissertation advisors/committee members, and at least ten other theses related to Soldier M&S. Students represented the US Army, US Navy, US Marine Corps, Singapore, Germany, and government civilians. Additionally, students and faculty used at least six existing simulation models, including Map Aware Non-uniform Automata (MANA), Pythagoras, the Infantry Warrior Simulation (IWARS), the Combined Analysis Tool for the XXIst Century (COMBAT^{XXI}), PAX, and the Recognition Primed Decision Model, as well as two simulations developed specifically by students for their research.

We supported the Soldier Modeling and Analysis Working Group (MAWG) by providing input and expertise into the processes of evaluating current Soldier modeling and simulation (M&S) capability gaps. Upon the completion of the Soldier MAWG effort and its transition to the Soldier FACT, we remained actively involved in the new organization by serving on the FACT's Executive Committee (EXCOM). In that role, we made recommendations for future critical research areas, participated in the research proposal process by recommending synopses for white papers and evaluating the resulting proposals, and conducted other supporting actions as appropriate. Additionally, we submitted proposals of our own to the process, two of which were selected for funding in FY06 and one in FY08.

We developed a prototype collaborative web portal to facilitate communication between Soldier M&S researchers, developers, and consumers that provides summaries of ongoing efforts and requirements. The web portal is not ready for launch, but is a viable proof-of-concept for future efforts.

This marks the end of the formal portion of this multi-year project; however, we will continue these efforts in the future as part of our normal operations. This technical report describes our efforts in detail, and includes synopses of each of the projects conducted in support of this project, a description of our TRAC-MTRY led Soldier M&S efforts, a summary of our participation in and support of the Soldier FACT, and a discussion of the development of the prototype Soldier M&S collaborative web portal.

Section 1 – Introduction

1.1. Background

US Army transformation to the Future Force continues to rely heavily upon the use of modeling and simulation (M&S) for analysis, including assessments of our ability to fight at every operational level from Corps down to the individual Soldier. Our military's involvement over recent years in Iraq, Afghanistan, Panama, Kuwait City, Haiti, Somalia, etc., have demonstrated that, in the modern battlespace, the actions and interactions of individuals, whether friendly, enemy, allied, or noncombatant, can have a tremendous impact on the outcome of military operations. In the Future Force, this will be especially true. Such concepts involve the Soldier as a System (SaaS), consisting of dispersed, networked Soldiers with increased firepower. As the Army considers the acquisition of these combat Soldier systems, M&S must be capable of sufficiently representing the Soldier system in varying environments.

Though M&S has played a large role in the development and refinement of Army tactics, techniques and procedures (TTP), current model research of individual behaviors on the battlefield had been fragmented and inadequately resourced. Core models were judged to be insufficient for the accurate simulation of individual combatant physical behaviors, as well as the representation of 'soft factors' (non-physical aspects, such as morale, discipline, fatigue, suppression, combat stress).

To combat these deficiencies, the Army Training and Doctrine Command (TRADOC) Analysis Center (TRAC) formed the Soldier Modeling and Analysis Working Group (MAWG) in 2003 and identified a prioritized list of deficiencies, or 'modeling gaps,' in the fidelity or level of detail of individual combatant representation across the existing suite of Army combat simulations. Identified gaps ranged from conceptually simple (a virtual infantryman's programmed inability to pick up a casualty's weapon to replace his own malfunctioning rifle) to extremely complex and challenging (simulated combatants currently ignore 'human factors' such as morale, exhaustion, combat stress, quality of leadership, etc.). The gaps, and the methodology for their identification, are detailed in the Soldier MAWG Evaluation Report.¹

¹ Larry Larimer, Pedro Habic, Tim Bosse, David Hardin, Doug Mackey, and Dan Tulloh, *Soldier Modeling and Analysis Working Group (MAWG) Evaluation Report*, TRAC-WSMR Technical Report, TRAC-WSMR-TR-04-009 (White Sands Missile Range, NM: TRAC-WSMR, 2004).

TRAC-MTRY's role as the research arm TRAC and its location on the Naval Postgraduate School campus places it in the unique position to conduct and influence Soldier M&S research in order to solve identified modeling deficiencies.

1.2. Research Overview

Anticipating the formation of a Soldier Focus Area Collaborative Team (FACT) as a follow-on to the Soldier MAWG efforts, we began a focused effort to seek out Naval Postgraduate School (NPS) students interested in working on thesis topics related to the gaps identified in the Soldier MAWG report. TRAC-MTRY had the resources to provide sponsored students with temporary duty (TDY) and experimentation funding, information technology (IT) support, office space, access to the Army's latest combat simulations, and thesis advisors and second readers. Additionally, we could provide resources to the world-class faculty at NPS for their support to Soldier modeling efforts. In return, the students and faculty provided timely, professional analysis that was immediately relevant to Soldier modeling.

In addition, we were positioned to lead and conduct larger, Soldier M&S efforts in support of Department of Defense (DOD) and Army sponsors. Most of those larger efforts involved some mix of student and faculty participation, as well as the focused efforts of TRAC-MTRY analysts.

When the Army Model and Simulation Office (AMSO, now an element of the Battle Command, Simulation and Experimentation (BCSE) Directorate of Army G3/5/7) formed the Soldier FACT to direct the Army's modeling research pertaining to Soldier representation, we saw an opportunity to contribute significantly to that process. The mission of the Soldier FACT is to facilitate Soldier M&S by developing, publishing and distributing a plan of research that highlights Army M&S priorities as they pertain to the Soldier.

Finally, the above efforts placed us in a position to communicate Soldier M&S efforts between and among M&S developers and consumers. Our efforts provided us a greater visibility of Soldier M&S efforts across the Army, DOD, industry, and academia. Therefore, we set out to develop a method of communicate Soldier M&S efforts and requirements across the broader community.

1.3. Research Objectives

The primary objectives of this project were three-fold:

- To leverage student thesis and dissertation work, as well as professor research, at NPS, in order to improve the M&S community's ability to model the individual Soldier and small units.
- To be a member of, and participate actively in, the Soldier FACT process as an Executive Committee (EXCOM) member.
- To develop lines of communication between consumers and developers of infantry (individual combatant) models, simulation, and data by providing a means to summarize current research efforts, challenges, and requests for information in a manner accessible to all stakeholders.

1.4. Limitation and Assumptions

1.4.1. *Limitation*

Researchers in support of this effort do not have visibility on Soldier modeling and simulation efforts across the military, industry, and academia. Lack of this knowledge may lead to duplication of effort and a failure to leverage other potentially-valuable research.

1.4.2. *Assumptions*

- Thorough background research should capture enough information concerning related efforts across the military, industry, and academia to minimize duplication of effort.
- A well-designed, accessible, and current Soldier M&S collaborative web portal will increase visibility of Soldier M&S efforts across the military, industry, and academia.

1.5. Supporting and Partner Agencies

There were many agencies that either directly or indirectly supported this research. The following is a list of the key organizations that contributed to this effort.

- Naval Postgraduate School, Monterey, CA.
- TRAC – White Sands Missile Range (TRAC-WSMR), WSMR, NM.
- US Army Materiel Systems Analysis Activity (AMSAA), Dismounted Infantry Team, Aberdeen Proving Grounds, MD.
- US Army Natick Soldier Center, Modeling and Analysis Team, Natick, MA.
- US Army Infantry School (USAIS) and Center (USAIC), Fort Benning, GA.
- Rolands and Associates Corporation, Monterey, CA.
- TRAC Methods and Research Office (TRAC MRO), Fort Leavenworth, KS.

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Section 2 – Research in Support of Soldier Modeling and Simulation

2.1. Technical Approach

2.1.1. NPS Student and Faculty Efforts

At the onset of this effort, we developed a four-phased approach to generate student and faculty interest and participation in Soldier M&S research.

The first phase involved selecting and defining several sets of research topics. We chose those topic areas from among the M&S gaps identified by the Soldier MAWG. Criteria for topic selection included the importance of closing the gap, the likelihood of generating student and faculty interest, and the feasibility of being addressed as a thesis or dissertation topic. The following list contains the ten original topic areas and includes a brief description of the area, a mapping to the Soldier MAWG categories, a suggested list of key factors, and potential research objectives.

- Reaction to Direct Fire.
 - Description: There is a need to model the basic behavior of Soldiers involved in a firefight.
 - S-MAWG Category: Situational Awareness, Lethality, and Survivability & Protection.
 - Factors: Visual and acoustic cues, posture, threat type, target selection/queuing, communications, effects, dynamic probabilities of hit (PH), tactical movements/battle drills, stress, suppression, search for cover.
 - Research Objective: Using visual and acoustic cues and threat type, model the basic behaviors/rules of the Soldier with respect to posture, target selection, and/or communication.
- Reaction to Indirect Fire.
 - Description: There is a need to model accurately the behavior of Soldiers receiving/observing indirect fire.
 - S-MAWG Category: Situational Awareness and Survivability & Protection.
 - Factors: Visual and acoustic cues, vibratory cues, distance/effects, training/experience, posture, mission, movement rates, search for cover, suppression.
 - Research Objective: Based on historical and doctrinally-correct actions, develop an algorithm based on training, effective area, and visual and acoustic cues to model the basic behaviors/rules of the Soldier when receiving indirect fire.
- Direct Fire Effects.
 - Description: There is a need to represent munitions effects on dismounted Soldiers. Non-fatal wounding is generally not represented.
 - S-MAWG Category: Lethality and Survivability & Protection.

- Factors: Accuracy/variance, impact point, posture, protective gear, movement rate, dynamic PH, suppression.
 - Research Objective: Using the posture of a Soldier, model precise, non-fatal munition effects on the Soldier.
- Soldier Accuracy Based on Time.
 - Description: There is a need to represent variable lay time and accuracy of a Soldier engaging targets in quick reaction and deliberate situations.
 - S-MAWG Category: Lethality and Survivability & Protection.
 - Factors: Exposure/lay time, dynamic PH, rate of fire, accuracy/variance, posture/support, target movement rate, distance.
 - Research Objective: Develop data/algorithms to model variable time engagements/PH.
- Soldier Accuracy Based Upon Posture.
 - Description: There is a need to represent the effects of different firing positions on engagement accuracy.
 - S-MAWG Category: Lethality and Survivability & Protection.
 - Factors: Posture/support, exposure/lay time, dynamic PH, rate of fire, accuracy/variance, target movement rate, distance.
 - Research Objective: Develop data/algorithms to model posture/support dependant PH and probabilities of kill (PK).
- Individual Weapon Capabilities in Urban Operations.
 - Description: Data does not exist for typical urban engagements of less than 50 meters.
 - S-MAWG Category: Lethality.
 - Factors: Rate of fire, exposure/lay time, distance, posture/support, dynamic PH, accuracy/variance, target queuing.
 - Research Objective: Conduct an analysis of historical data for the M16/M4 and M249 in recent urban conflicts (Somalia, Afghanistan and Iraq) to yield models and data for PH of these weapon systems.
- Soldier Load / Fatigue.
 - Description: There is a need to better understand and represent elements, other than speed, of the Soldier's performance that are affected by fatigue due to Soldier load.
 - S-MAWG Category: Mobility.
 - Factors: Weapon/gear/casualty carried, reaction/engagement time, fatigue, tactical movement, posture, terrain.
 - Research Objective: Using historical data, model fatigue and its effects on the Soldier.
- Semantic Terrain.
 - Description: Acquisition data is needed to allow entities to acquire or be cued to bunkers, fighting positions, and other 'danger areas.'
 - S-MAWG Category: Lethality.
 - Factors: Visual and acoustic cues, threat recognition, threat location approximation, communication, line of sight, training/experience.

- Research Objective: Better represent the Soldier’s ability to acquire, recognize, and engage targets other than Soldiers and vehicles.
- Human Factors.
 - Description: There is a need to identify and represent human factor effects.
 - S-MAWG Category: Survivability & Protection.
 - Factors: Fatigue, stress, experience/training, emotion, personality, physical/cognitive resources.
 - Research Objective: Identify and develop data/algorithms of how different human factors such as stress affect Soldier performance.
- Cover and Concealment.
 - Description: There is a need to represent how a Soldier finds and uses cover and concealment.
 - S-MAWG Category: Modeling the Environment and Survivability & Protection.
 - Factors: Posture, exposed area, material composition, dynamic PH, weapon type.
 - Research Objective: Develop data/algorithms for how the Soldier finds and uses typical objects as cover.

The second phase involved the identification of potential students and faculty. Our approach consisted of frequent meetings with students and faculty, briefings presented to faculty in NPS department forums, briefings to student cohorts, guest lectures in classes, and combat modeling laboratory tours and presentations. Students we pursued were members of all US Armed Services, as well as government civilians and foreign military officers.

The third phase consisted of working with students and faculty to scope their research topics and guide their efforts throughout the conduct of the research. Scoping the research involved working with students to develop their thesis and dissertation proposals and with faculty to develop research proposals. Once the proposals were developed, we often served as second readers for student theses and advisors or committee members for Ph.D. dissertations. Throughout the conduct of the research, we provided guidance to ensure that student and faculty efforts provided value to the Army. Additionally, we were able to provide the students resources, such as TDY funds, computer lab access, and work space to enable their research and to compensate faculty members for their time and efforts. Another key aspect of our role in this regard was our ability to serve as a link for the students and faculty to other Army agencies and stakeholders.

The fourth and final phase involved consolidating and reporting the results of the research. Upon completion of student and/or faculty research, we provided the vital link to the

Army to ensure that results of the research were shared with those who should be interested. It is important to note that we did not only do this for topics that we sponsored, but for other student and faculty research relating to Soldier M&S that we identified as well. Students and faculty at NPS were involved in many Soldier M&S topics in support of other Services and agencies. We ensured that we maintained visibility of those efforts as well.

2.1.2. *TRAC-MTRY Efforts*

In addition to garnering NPS student and faculty interest, TRAC-MTRY also pursued Soldier-related M&S research projects in support of its work program. Our methods for developing these projects included meetings with organizations who would have interest in Soldier M&S, such as Program Executive Office Soldier (PEO Soldier), the Future Force Warrior (FFW) Technology Program Office (TPO), TRAC-WSMR, Air Force Research Lab (AFRL), the US Army Materiel Systems Analysis Activity (AMSAA), the US Army Natick Soldier Center, the Soldier Battle Lab (SBL) and others. Additionally, we developed proposals as part of the Soldier FACT process.

2.2. Results

We were very successful in getting the support of numerous students and faculty during the conduct of this three-year effort. In fact, during this timeframe, we attracted or shared the research of 24 students in two NPS Departments, at least seven NPS Ph.D. faculty members, 12 theses and dissertations for which TRAC-MTRY served as second readers or dissertation advisors/committee members, and at least ten other theses related to Soldier M&S. Students represented the US Army, US Navy, US Marine Corps, Singapore, Germany, and government civilians. Additionally, students and faculty used at least six existing simulation models, including Map Aware Non-uniform Automata (MANA), Pythagoras, the Infantry Warrior Simulation (IWARS), the Combined Analysis Tool for the XXIst Century (COMBAT^{XXI}), PAX, and the Recognition Primed Decision Model, as well as two simulations developed specifically by students for their research.

The following paragraphs give a brief description of each of the Soldier M&S related efforts, both those that we sponsored and those that we identified as relating to Soldier M&S. They are grouped by year, with the most recent first. For each effort, we provide the title of the

thesis or dissertation, and the abstract from the student's final report, as well as whether TRAC-MTRY served in the role of a second reader, advisor, or committee member.

2.2.1. NPS Student Efforts in 2006

Modeling Macro-Cognitive Influence on Information Sharing between Members of a Joint Team, Steve Burnett, Civilian, TRAC-MTRY member on Dissertation Committee:

Research exploring the effectiveness of joint military teams lacks the empirical robustness found in similar multicultural team research from the business domain. This research study broadens the study of effective military teams through an assessment of the factors that influence a joint team's effectiveness by capitalizing on the business and psychological communities' exploration of successful team performance. Specifically, in three empirical studies, this research examines several key elements of poor team effectiveness identified by the business community, namely cultural differences and personality stereotypes. Study One examined cultural orientation and service personality using a survey instrument. The results show that cultural and personality differences exist at significant levels between the services. The second study examined team information sharing processes in a wargame environment composed of homogeneous and heterogeneous four-person teams. The results revealed that participants in heterogeneous teams, cued to the presence of cultural and personality differences among team members, performed as well as homogeneous teams. The third study expands the knowledge space of the team experiment by developing an agent-based model replicating the wargame. The model accurately represented the experimental data, confirming our hypothesis that computational models coded with actual data sets from human experimentation are more robust than models coded with notional data sets. The results demonstrate that joint team effectiveness improves by incorporating methodologies used in the business and simulation science communities.²

Communication Aspects in Urban Terrain, Volker Pfeiffer, German Army:

The nature of warfare has changed dramatically during the last decade. Western armies are increasingly required to conduct complex operations in urban terrain against asymmetric threats. These opponents use cities and their inhabitants for cover and concealment. In such situations, modern equipped armies often cannot fully utilize many of their most powerful weapons. To overcome this situation, modern communication systems are being acquired and deployed to provide real-time reconnaissance; thereby, attempting to neutralize the threat through enhanced situational awareness. This research addresses the potential impacts of communication from airborne sensors on assisting a convoy in finding its way through a hostile city quarter (based on Mazar-E-Sharif, Afghanistan) in which militia forces try to interdict them via street blockades and ambushes. The implementation is done in the agent-based simulation Map Aware Non-Uniform

² Steve Burnett, *Modeling Macro-Cognitive Influence on Information Sharing between Members of a Joint Team*, Ph.D. Dissertation (Monterey, CA: Naval Postgraduate School, 2006).

*Automata (MANA). The results show that the current MANA version is not sufficiently capable to handle routing problems in urban terrain. Specifically, the movement algorithm is 'locally greedy' and not flexible enough to project into the future as real human decision makers do. Many workarounds were developed to mitigate this limitation. The analysis shows that the number of blockades is the single most important factor in determining the convoy's success. Of the communication factors, network latency has the most impact. For the convoy to effectively use the information, it needs to get from the sensor to the convoy in 11 seconds.*³

Effectiveness of Non-Lethal Capabilities in a Maritime Environment, Lisa Sickinger, US

Navy:

*The attack on the USS Cole within a civilian port, and the increased threat of pirating and terrorism on the high seas, underscore the immediate need for a maritime non-lethal capability. This research uses modeling and simulation to explore the requirements and tactical use of non-lethal capabilities in a maritime force protection mission. Specifically, a multi-agent simulation emulates a tactical-level mission in which a U.S. Navy vessel returning to Naval Station, Norfolk, VA, encounters a variety of maritime surface threats. Data farming is the method used to address the research questions by applying high performance computing to the simulation model, with the intent of examining a wide range of possibilities and outcomes. The non-lethal capabilities are analyzed in their effectiveness to 1) determine intent, 2) deter inbound surface vessels, and 3) engage targets identified as hostile through the continuum of force.*⁴

Exploration of Force Transitions in Stability Operations Using Multi-Agent Simulation,

David Vaughan, US Marine Corps:

Stability Operations have become the most prevalent mission for U.S. forces in the current global security environment. This research explores new methods to assist in determining when it is acceptable to downsize a force in a stability operation. The methodology developed provides insight into this problem by quantifying force protection risk, mission failure risk, and time in the context of the operational threat environment. The Pythagoras Multi-Agent Simulation and Data Farming techniques are used to investigate force-level comparison in a theoretical threat continuum based on a peacekeeping scenario similar to the Bosnian operation. The data from the simulation is to construct simple tools for decision makers. These tools are used collectively to find the balance, according to a commander's priorities, between the conflicting issues of force protection, mission success, and time. Two areas are identified as significant in achieving success in stability operations. They are troop posturing and troop employment. The problem is that they are often overlooked or under emphasized. The result of

³ Volker Pfeiffer, *Communication Aspects in Urban Terrain*, Masters Thesis (Monterey, CA: Naval Postgraduate School, 2006).

⁴ Lisa Sickinger, *Effectiveness of Non-Lethal Capabilities in a Maritime Environment*, Masters Thesis (Monterey, CA: Naval Postgraduate School, 2006).

*this research demonstrates that posturing and employment should be considered as factors equal to force size in contributing to the goal of maximizing force presence. In addition, this research provides a vehicle to assist military planners with ways in which a stability force can maximize and maintain near continuous presence, while simultaneously minimizing the risk to the force and adhere to operational timelines. Overall, the important conclusion in the significance of troop posture on force size transitions. As a force is downsized, it is crucial to evaluate how to maintain presence with the smaller force. This is evident by the surprising success achieved by the smallest force in the simulation. It was able to project a greater presence by utilizing small dispersed units, much like the Combined Action Platoons in Vietnam.*⁵

An Upgradeable Agent-Based Model to Explore Non-linearity and Intangibles in Peacekeeping Operations, Wolfgang Lehmann, German Army:

*Peacekeeping operations (PKO) have become a significant challenge to the German Armed Forces. For the development of tactics, techniques, procedures and equipment with combat operations, agent-based models have been developed, used and exploited for many years. Modeling and simulation of PKO, however, is still in a very early stage. This thesis develops an agent-based model to analyze PKO. Unlike many other multi-agent systems (MAS), it implements the rules of discrete event simulation. The chosen software architecture makes the model upgradeable and useful for a breadth of future applications. The model's open architecture and the underlying principle of loosely coupled components make it easy to change or enhance the model. The software agents' design incorporates individuality, which is characterized by personality factors. Furthermore, the model is data-farmable. Required data inputs into the simulation tool, i.e., PKO scenarios, are formatted utilizing a state-of-the-art technology called Extensible Markup Language (XML), which facilitates use of the data in nearly all computer software packages. The model executes multiple runs of multiple scenarios automatically, demonstrating a robust nature. Finally, an exemplary analysis demonstrates data-farming concepts on the effect of personality factor settings on the potential escalation of a PKO scenario.*⁶

Human Behavior Representation of Military Teamwork, Michael Martin and Jon Ellis, US Army, TRAC-MTRY member as Second Reader:

This work presents a conceptual structure for the behaviors of artificial intelligence agents, with emphasis on creating teamwork through individual behaviors. The goal is to set up a framework which enables teams of simulation agents to behave more realistically. Better team behavior can lend a higher fidelity of human behavior representation in a simulation, as well as provide opportunities to experiment with the factors that create teamwork. The framework

⁵ David Vaughan, *Exploration of Force Transitions in Stability Operations Using Multi-Agent Simulation*, Masters Thesis (Monterey, CA: Naval Postgraduate School, 2006).

⁶ Wolfgang Lehmann, *An Upgradeable Agent-Based Model to Explore Non-linearity and Intangibles in Peacekeeping Operations*, Masters Thesis (Monterey, CA: Naval Postgraduate School, 2006).

*divides agent behaviors into three categories: leadership, individual, and team-enabling. Leadership behaviors consist of planning, decision-making, and delegating. Individual behaviors consist of moving, shooting, environment-monitoring, and self-monitoring. Team-enabling behaviors consist of communicating, synchronizing actions, and team member monitoring. These team-enabling behaviors augment the leadership and individual behaviors at all phases of an agent's thought process, and create aggregate team behavior that is a hybrid of emergent and hierarchical teamwork. The net effect creates, for each agent, options and courses of action which are sub-optimal from the individual agent's standpoint, but which leverage the power of the team to accomplish objectives. The individual behaviors synergistically combine to create teamwork, allowing a group of agents to act in such a manner that their overall effectiveness is greater than the sum of their individual contributions.*⁷

2.2.2. NPS Student Efforts in 2005

The Effects of Military Tactics, Techniques, and Procedures on Peace Support Election Operations in Representative Iraqi Towns, Han Hiong Ang, Singapore Civilian:

*The complexity of Peace Support Operations (PSO) requires that a wide variety of aspects and possible effects be considered. Unlike traditional analysis of combat operations, the analysis of PSO aims at avoiding conflict situations, where losses or injuries are to be minimized for all participants involved. Election scenarios in a homogeneous (Sunni) and a heterogeneous (Sunni, Shiite/Kurd) populated representative Iraqi town are developed to evaluate and gain insights on the proposed military tactics, techniques and procedures for the PSO, which may affect the outcome of the election. An agent-based modeling platform designed specifically for PSO is used to model the evolving behavior of civilian individuals and their influences on the emerging behavior of groups. An efficient experimental design, with excellent space filling and orthogonality properties, is employed to gather data from the simulation over a broad variety of scenarios. The voter participation rates, escalation among civilians, and civilian-military interactions are the primary measures of effectiveness. The results indicate that several military measures contribute to a successful election. These include the execution of security control regions, the deployment of election booths intended to calm the crowd and encourage voter participation, and attempts to quell unrest by seeking the cooperation of civilian leaders. Factors such as Soldiers' rules of engagement, civilian fear and anger personalities and their variability also play important roles in the escalation or de-escalation of civilian behavior.*⁸

⁷ Michael Martin and Jon Ellis, *Human Behavior Representation of Military Teamwork*, Masters Thesis (Monterey, CA: Naval Postgraduate School, 2006).

⁸ Han Hiong Ang, *The Effects of Military Tactics, Techniques, and Procedures on Peace Support Election Operations in Representative Iraqi Towns*, Masters Thesis (Monterey, CA: Naval Postgraduate School, 2005).

Supporting a Marine Corps Distributed Operations Platoon: A Quantitative Analysis,

Matthew Bain, US Marine Corps:

This research analyzes the critical logistical requirements of a U.S. Marine Distributed Operations Platoon with the goal of developing a sustainable support plan. The development of Distributed Operations (DO) is one of the Marine Corps' major transformational efforts. The concept is designed to make infantry units more lethal by leveraging training and technology to allow more dispersed and intelligence driven operations. Since a DO platoon will operate far from secure lines of communication and support bases, logistically supporting it will be challenging. Through the use of simulation, statistical analysis, and logistical modeling, this thesis identifies critical factors and capabilities that are important to the sustainment of a DO platoon operating from a Marine Expeditionary Unit (MEU). The research concludes with a feasible support concept combined with the means to assess the effect that supporting a DO platoon has on other MEU missions. Results indicate that quick response time and dedicated support assets from the supporting agency, typically augmented by MEU helicopters, are critical to the success of a DO platoon. This limits the flexibility of the MEU aviation element to support other MEU missions. The biggest payoff in improving logistical effectiveness is given by reducing the response time.⁹

Comparison of a Distributed Operations Force to a Traditional Force in Urban Combat,

Michael Babilot, US Marine Corps:

Two motivations drove this study of the Distributed Operations Platoon (DO) in urban combat: (1) the Marine Corps Warfighting Lab (MCWL) is developing the concepts to apply to a DO in the Sea Viking 2006 experiment and (2) Marines are engaged daily in urban combat in support of the Iraq reconstruction efforts. This thesis explores whether a DO is suitable for urban combat operations by analyzing the results of simulations created in Map Aware Non-uniform Automata (MANA). The employment of a DO is compared to employment of a traditional Marine infantry platoon in an urban combat scenario based upon data obtained from Operation al-Fajr, conducted in Fallujah, Iraq, in November 2004. The study also examines the effects caused by varying the terrain to that of Range 200, constructed at the Marine Air Ground Training Command, Twentynine Palms, California. Modeling insights, obtained by surveying Marines with urban combat experience in Iraq, tie into the research effort. This research indicates that the DO is marginally more effective than a Traditional Platoon in urban combat. DO also shows a greater sensitivity to combat outcomes due to urban density, and produced significantly better results in terrain with a lesser density of urban structures.¹⁰

⁹ Matthew Bain, *Supporting a Marine Corps Distributed Operations Platoon: A Quantitative Analysis*, Masters Thesis (Monterey, CA: Naval Postgraduate School, 2005).

¹⁰ Michael Babilot *Comparison of a Distributed Operations Force to a Traditional Force in Urban Combat*, Masters Thesis (Monterey, CA: Naval Postgraduate School, 2005).

Exploring the Effectiveness of the Marine Expeditionary Rifle Squad, Todd Sanders, US Marine Corps:

*This study explores the effectiveness of the Marine Expeditionary Rifle Squad (MERS) in support of Distributed Operations in urban terrain. The Marine Corps is evaluating the Distributed Operations concept as a solution to new threats posed in current operations. In order to employ distributed tactics, a more effective and capable Marine Rifle Squad is needed. The MERS concept seeks to increase the effectiveness of the current rifle squad, enabling smaller, more lethal, and more survivable units. Those issues are explored using agent-based modeling and data analysis. The most significant finding is that the MERS must be evaluated as a system; factors cannot be analyzed in isolation. The two factors that most affect the effectiveness are survivability and lethality. Maximizing these two factors leads to the lowest friendly casualties, highest enemy casualties, and highest probability of mission success. Agent-based modeling provides the maximum flexibility and responsiveness required for timely insights into small unit combat.*¹¹

Modeling Sound as a Non-Lethal Weapon in the COMBAT^{XXI} Simulation Model, Joseph Grimes, US Army, TRAC-MTRY member as Second Reader:

*Modeling and representing combat and individual Soldiers is a complex task. Several factors influence combatant behavior. Using non-lethal methods has become one way for combatant commanders to accomplish their wartime mission. Current the Army and Marine Corps models are not capable of non-lethal weapon replication. The Training and Doctrine Command Analysis Center (TRAC) Monterey California has funded a program of research related to individual combatant representation in modeling and simulation. Modeling non-lethal weapons was identified by TRAC-Monterey as important to better represent actual combat. This thesis used COMBAT^{XXI}, a high-resolution, closed-form, stochastic, analytical combat simulation, to replicate non-lethals and study the effects on individual combatants. Existing source code was modified to model the Long Range Acoustic Device (LRAD), the non-lethal platform chosen for this research. LRAD is an acoustic device designed to modify the behavior of personnel with a high intensity warning tone. Once the LRAD capability was developed, a scenario was developed to test the simulated effects of the device. A model was developed to accurately determine behaviors of individual combatants. It was concluded that the implementation of this new non-lethal capability in COMBAT^{XXI} improved the model and created a more realistic representation of actual combat conditions.*¹²

¹¹ Todd Sanders, *Exploring the Effectiveness of the Marine Expeditionary Rifle Squad*, Masters Thesis (Monterey, CA: Naval Postgraduate School, 2005).

¹² Joseph Grimes, *Modeling Sound as a Non-Lethal Weapon in the COMBAT^{XXI} Simulation Model*, Masters Thesis (Monterey, CA: Naval Postgraduate School, 2005).

The Effects of Posture, Body Armor and Other Equipment on Rifleman Lethality, Gary Kramlich, US Army, TRAC-MTRY member as Second Reader:

How does body armor and posture affect Soldier marksmanship? The Interceptor Body Armor (IBA) has significantly improved Soldier combat survivability, but in what ways does it change rifleman lethality? Moreover, can we model these effects so as to develop better tactics and operational plans? This study quantifies the effects of Soldier equipment on lethality through multi-factor logistic regression using data from range experiments with the 1st Brigade, 1st Infantry Division (Mechanized), at Fort Riley, Kansas. The designed experiment of this study estimates the probability of a qualified US rifleman hitting a human target. It uses the rifleman's equipment, posture, Military Occupational Specialty (MOS), and experience along with the target's distance, time exposure and silhouette presentation as input factors. The resulting family of mathematical models provides a Probability of Hit prediction tailored to a shooter-target scenario. The study shows that for targets closer than 150 meters, Soldiers shot better while wearing body armor than they did without. Body armor had a negative effect for targets farther than 200 meters, and this could significantly impact the employment of the Squad Designated Marksman. The study also shows that the kneeling posture is an effective technique and recommends standardized training on this method of firing.¹³

Event Prediction for Modeling Mental Simulation in Naturalistic Decision Making, Dietmar Kunde, German Army, TRAC-MTRY member as Ph.D. Dissertation Advisor:

Nearly all armies of the Western Hemisphere use modeling and simulation tools as an essential part of performing analysis and training their leaders and war fighters. Tremendous resources have been applied to increase the level of fidelity and detail with which real combat units are represented in computer simulations. Current models digress from Lanchester equations used for modeling the big Cold War scenarios towards modeling of individual Soldier capabilities and behavior in the post Cold War environment and increasingly important asymmetric warfare scenarios. Although improvements in computer technology support more and more detailed representations, human decision making is still far from being automated in a realistic way. Many "decisions" within a simulation are based on overly simple models and hardly at all on cognitive processes. One cognitive model in naturalistic decision making is the Recognition Primed Decision Model developed by Klein and Associates. It describes how the actual process humans use to come up with decisions in certain situations is radically different from the traditional model of rational decision making. Mental simulation is an essential part of this model in order to picture possible outcomes in the future for potential courses of actions. This research provides a computational model for mental simulation in a combat simulation environment. It generates the look into the near future with a finite Markov Chain as one

¹³ Gary Kramlich, *The Effects of Posture, Body Armor and Other Equipment on Rifleman Lethality*, Masters Thesis (Monterey, CA: Naval Postgraduate School, 2005).

*instance of several possible predictive models. The results of the model are compared with preliminary human experimental data. The experiments show that the model developed performs in the human range with respect to prediction and decisions. This research shows that entities in a combat simulation environment having the capability of looking ahead into the near future based on statistical data perform more realistically than those that just use the information of the present, not even including the past.*¹⁴

Auditory Detection and Sound Localization for Computer-Generated Individual Combatants, John Michaud, US Army, TRAC-MTRY member as Second Reader:

*Soldiers rely predominantly on vision to detect targets, yet other senses may cue their sense of sight. Contrarily, most army combat simulations employ only visual cues. The focus of this thesis is to enhance combat simulations by providing a method by which computer-generated entities can detect and locate objects via a phenomenon known as "sound localization." The Auditory Detection Program is used to represent a human's hearing, and data from a sound localization experiment are analyzed to determine how to best represent the event in which an individual hears a sound and then estimates the location of the sound's source. The resulting algorithms are coded into the Army's combat simulation, COMBAT XXI, and the "face-validation" method is used to determine if the algorithms enhance the realism of the simulation. The data analysis consists of Shapiro-Wilks Tests for Normality [sic], Friedman's Tests for Randomized Block Experiment, and Wilcoxon Rank-Sum Tests using the Bonferroni Correction. Implementing this model in COMBAT XXI improves the simulation by making it more realistic.*¹⁵

Games for Training: Leveraging Commercial Off the Shelf Multiplayer Gaming Software for Infantry Squad Collective Training, Joseph Nolan and Jason Jones, US Army, TRAC-MTRY member as Second Reader:

Combat arms units (both Marine and Army) often do not have enough people, time and resources to properly train collective tasks at the squad level. Resources are often retained by higher headquarters due to tight deployment schedules, land restrictions, logistics constraints and a myriad of other reasons. Due to the current operational demands of combat arms brigades and regiments, the reality of limited resources is often a contributing factor in poor performance at the squad level. Leaders at all levels will need to look for innovative ways to sustain training levels at the small unit level. The scope of this study examined the collective and leader tasks that are required for successful execution of Infantry squad missions (using the Army Training and Evaluation Plan ARTEP 7-8 Drill), and how those tasks could be trained with the use of commercial off-the-shelf multiplayer gaming software. The end-state of this research study is to provide

¹⁴ Dietmar, Kunde, *Event Prediction for Modeling Mental Simulation in Naturalistic Decision Making*, Ph.D. Dissertation (Monterey, CA: Naval Postgraduate School, 2005).

¹⁵ John Michaud, *Auditory Detection and Sound Localization for Computer-Generated Individual Combatants*, Masters Thesis (Monterey, CA: Naval Postgraduate School, 2005).

*initial analysis on what collective skills games can be used to train at the Infantry squad level, and develop a training model recommendation for the integration of this tool into existing unit plans.*¹⁶

Applied Warfighter Ergonomics: A Research Method for Evaluating Military Individual Equipment, Koichi Takagi, US Marine Corps, TRAC-MTRY member as Second Reader:

*The objective of this research effort is to design and implement a laboratory and establish a research method focused on scientific evaluation of human factors considerations for military individual equipment under both laboratory and field conditions. This integrated approach for laboratory and field conditions is the first of its kind for military human factors research, enabling an unparalleled degree of scientific rigor in the collection of empirical human factors data. This effort includes: 1) a state-of-the-art usability laboratory designed specifically for quantitatively evaluating military individual equipment; 2) a rugged, embarkable, fully self-contained, portable usability laboratory for field research in military environments; 3) a codified manual for using the two main configurations (stationary and portable) of the usability laboratory, written for the beginning usability researcher; 4) a set of validated procedures for applying sound human factors principles, and traditional and non-parametric statistics to the specific problem of usability testing of military individual equipment; 5) a proof-of-concept practical application of the laboratory and procedures to a specific problem, namely the usability testing of ruggedized personal digital assistants (RPDAs) designed for United States Special Forces operations.*¹⁷

2.2.3. NPS Student Effort in 2004

Modeling How Individual Entities React to Indirect Fire, Brent Streater, US Army:

Current Army models and simulations provide limited representation of the actions and behaviors of the individual combatant (Soldier, Sailor, Marine, or Airman). As the Army transforms into the Future Force, more emphasis is being placed on modeling the actions and behaviors of the individual combatant. The Training and Doctrine Command Analysis Center – Monterey has initiated the Individual Combatant Research Project. One research area is modeling how individual entities react to indirect fire, which is the focus of this thesis. From a study of both historical examples and current U.S. Army doctrine, we derived the input factors and responses. We selected the most significant input factors and derived a general model to represent this phenomenon. From the general model we derived a specific model that we implemented as a behavior rule using the Combined Arms Analysis Tool for the 21st Century, CXXI. In order to determine the effectiveness of the model, we used the face validation method. Our data analysis consisted of a two-sample t-test, a Mann-Whitney test, and a two-way analysis of variance. From our analysis we concluded that implementation of our

¹⁶ Joseph Nolan and Jason Jones, *Games for Training: Leveraging Commercial Off the Shelf Multiplayer Gaming Software for Infantry Squad Collective Training*, Masters Thesis (Monterey, CA: Naval Postgraduate School, 2005).

¹⁷ Koichi Takagi, *Applied Warfighter Ergonomics: A Research Method for Evaluating Military Individual Equipment*, Masters Thesis (Monterey, CA: Naval Postgraduate School, 2005).

*model in CXXI was an improvement that made CXXI more realistic and functional.*¹⁸

2.2.4. TRAC-MTRY Work Program Research Overview

We were also very successful in our efforts to develop projects in support of Soldier M&S. We developed two projects in support of the FFW Advanced Technology Demonstration (ATD); one project in support of the Land Warrior (LW) program; a project in support of AFRL's chemical, biological, radiological, nuclear (CBRN) tactical situational awareness efforts; and three projects as part of the Soldier FACT process. The following sections briefly describe each of those projects and supporting theses.

2.2.5. FFW TTP and Capability Analysis, FY06

The Future Force Warrior Advanced Technology Demonstration sought to increase the combat effectiveness of the dismounted infantry Soldier and his associated Small Combat Unit (SCU) through improvements in lethality, survivability, and situational awareness. These improvements stem primarily from new equipment and networked indirect-fires. The incorporation of these capabilities into tactics, techniques, and procedures (TTP) and the determination of best practices must occur prior to battlefield testing. This research examined the TTP for three tasks of an FFW-equipped SCU in a night, urban setting and focused on identifying potential changes in the TTP of each task using the Pythagoras agent based model. Additionally, this research addressed the distribution of capabilities across an FFW-equipped squad in a night, urban react-to-contact scenario using the Infantry Warrior Simulation (IWARS). Finally, this research examined the impact of equipping an FFW equipped squad with non-lethal weapons (one of the Ground Soldier System end-state capabilities), using Pythagoras. The analysis provides a starting point for further analysis using more detailed models, war-fighting experiments and real-world data.¹⁹

There were three student theses in support of this project. They are described in the following paragraphs.

¹⁸ Brent Streater, *Modeling How Individual Entities React to Indirect Fire*, Masters Thesis (Monterey, CA: Naval Postgraduate School, 2004).

¹⁹ Jonathan Alt, Eric Tollefson, and Jeffrey Schamburg, *Future Force Warrior Tactics, Techniques, and Procedures and Capability Analysis*, TRAC-MTRY Technical Report (Monterey, CA: TRAC-MTRY, TBP).

Exploring Tactics, Techniques and Procedures for a Future Force Warrior Small Combat Unit, Jon Alt, US Army, TRAC-MTRY member as Second Reader:

*The Future Force Warrior Advanced Technology Demonstration seeks to increase the combat effectiveness of the dismounted infantry Soldier and his associated Small Combat Unit (SCU) through improvements in lethality, survivability, and situational awareness. These improvements stem primarily from new equipment and networked indirect-fires. The incorporation of these capabilities into tactics, techniques, and procedures (TTPs) and the determination of best practices must occur prior to battlefield testing. This research shows the suitability of a constructive multi-agent simulation in evaluating TTPs for new or existing capabilities. In addition, insights are gained into the two specific TTPs examined: react-to-contact and enter-and-clear a building. Utilizing a Nearly Orthogonal Latin Hypercube design, up to 38 factors are examined in 268,500 computational experiments. The results identify for the decision maker pairings of friendly and enemy courses of actions and actions on contact that produce the best outcomes for friendly forces or which should be avoided. More importantly, the methodology identifies those robust TTPs that perform well under a variety of conditions. These should be considered for further evaluation and adoption as TTPs. In addition, this analysis shows that the SCU must be examined as a system to fully capture the complex interactions of dismounted operations.*²⁰

Analyzing the Distributed Capabilities of the Future Force Warrior Small Combat Unit (FFW SCU), Earl Richardson, US Marine Corps, TRAC-MTRY member as Second Reader:

*This study explores several proposed capabilities of the Future Force Warrior Small Combat Unit (FFW SCU) program. The goal is to analyze the advanced, integrated capabilities of the FFW SCU in order to find the configuration of weapons and equipment that will increase the combat effectiveness of SCUs. The Infantry Warrior Simulation (IWARS) will be used to model the dismounted combat operations capabilities of the FFW SCU. IWARS is a new, constructive, agent-based combat simulation tool created by the Anteon Corporation and co-developed by the Natick Soldier Center. This thesis is the first study to use the IWARS program and challenge the simulation program's capabilities. It also serves as a template of the methodology that can be used for future FFW studies. One major insight is that two different weapon and equipment mixes lead to high levels of combat effectiveness for this scenario. In the first, all the indirect capabilities (Netted Fires, Netted Communications, Cooperative Engagement, integrated UAV and SUGV) should be available. In the second, all members of the squad should have Reduced Exposure capability and at least two members of the fire team or four members of the squad should have the Fused Sensor capability.*²¹

²⁰ Jonathan Alt, *Exploring Tactics, Techniques and Procedures for a Future Force Warrior Small Combat Unit*, Jon Alt, US Army, Masters Thesis (Monterey, CA: Naval Postgraduate School, 2006).

²¹ Earl Richardson, *Analyzing the Distributed Capabilities of the Future Force Warrior Small Combat Unit (FFW SCU)*, Masters Thesis (Monterey, CA: Naval Postgraduate School, 2006).

An Exploration of Equipping a Future Force Warrior Small Combat Unit with Non-Lethal Weapons, Larry Wittwer, US Army, TRAC-MTRY member as Second Reader:

The U.S. military has an increasing requirement to prepare for and conduct urban operations (UO). This UO requirement spreads across the spectrum of conflict, from high intensity combat to peacekeeping and humanitarian missions (Stability and Support Operations--SASO), often simultaneously. Regardless of which portion(s) of the warfare spectrum U.S. forces are involved in, urban engagements are inevitable and present major challenges. Superior standoff weapons ranges and combined arms tactics are quickly negated in the confined terrain of a complex and usually unfamiliar urban environment. Often considerably more challenging is the ability to differentiate the enemy from noncombatants--endangering our Soldiers and their mission. Conventional forces, armed only with traditional weapons, normally have two options: the threat of a violent response (passive) or the use of deadly force (active). These two extremes have virtually no middle ground. The reluctance of military and/or peacekeeping forces to employ deadly force on unconfirmed enemy targets creates a vulnerability. This vulnerability may be mitigated by equipping a small combat unit (SCU) with a viable alternative to deadly force-- non-lethal weapons (NLWs). Using an imperfect friend or foe identification modeling framework within an agent-based simulation (ABS), an NLW is essentially used to interrogate (determine the intent of the person in order to identify friend or foe) rather than attempt to incapacitate a target. To determine the impacts of employing NLWs in an urban combat environment (with civilians on the battlefield), three factors were varied across 15 design points: the ability of U.S. military forces to positively identify a target, the range of the selected NLW, and the distribution/number of NLWs in an SCU. By replicating each design point and analyzing the resulting output data, the following insights were determined: the use of NLWs does not degrade U.S. survivability; NLWs are essential to neutralizing suicide attacks; and NLWs decrease civilian casualties.²²

2.2.6. Future Force Warrior Experimental Design and Analysis, FY07

In this follow-on research to our FY06 efforts, we developed and implemented an experimental design in support of the FFW program's evaluation of exit criteria and essential elements of analysis (EEA). The experimental design encompassed both live experimentation and constructive simulation. Live experimentation support consisted of the construction of operational vignettes, development of data collection instruments, and development and onsite supervision of a data collection plan. Constructive simulation in support of this evaluation is ongoing.

²² Larry Wittwer, *An Exploration of Equipping a Future Force Warrior Small Combat Unit with Non-Lethal Weapons*, Masters Thesis (Monterey, CA: Naval Postgraduate School, 2006).

The end-of-exercise questionnaires developed for this experiment were extremely valuable and can be used again by the FFW program for subsequent experiments and for comparing future results to this analysis. Such analysis could provide the program with useful information about the training time required for the systems and allow them to gauge whether the systems had been adjusted to better serve the users' needs.

The Geographical Recall and Analysis of Data in the Environment (GRADE) situational awareness measurement technique and the Dynamic Model of Situated Cognition (DMSC) paradigm used as part of this analysis can be applied to future work in analyzing the impact of systems designed to improve or enhance situational awareness. These tools have application across the levels of command and are timely and relevant given the information-centric nature of the Future Force.

The evaluation of the program's exit criteria synthesized the system's performance on objective technical performance measures, the results of focus group interviews and end-of-exercise questionnaires, and the results of the GRADE measurement of situational awareness. The EEA associated with each exit criteria were examined based on the results of the experimentation. The FFW program can use this evaluation to determine areas to sustain, improve and to conduct further testing to gain further insight into the EEA.²³

One student, CPT Richard Brown, US Army, developed his thesis in support of this effort, with a TRAC-MTRY member is serving as second reader. As part of his research, he developed use case scenarios within the IWARS model. Using selected EEA identified for exploration within IWARS, he updated his scenario files with the data obtained from the live experimentation events. In order to explore the parameter spaces for a given scenario effectively, CPT Brown used advanced experimental design and efficient execution of that design within a high performance computing environment. Based upon the results of the experimental design runs, he was able to draw valuable insights concerning the particular EEA selected for his analysis.

2.2.7. Land Warrior / Mounted Warrior DOTMLPF Assessment Survey Support, FY07

In March of 2006, the Land Warrior (LW) / Mounted Warrior (MW) Doctrine, Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, Facilities (DOTMLPF)

²³ Jonathan Alt, Eric Tollefson, Eugene Fober, Daniel Turner, and William Harris, *Future Force Warrior Experimental Design and Analysis*, TRAC-MTRY Technical Report (Monterey, CA: TRAC-MTRY, TBP).

Assessment analysis lead at TRAC-WSMR approached TRAC-MTRY for assistance in the development, administration, and analysis of questionnaire and interview data collection efforts in support of the assessment. The primary objectives of the Consolidated Survey effort were threefold: 1) to design and administer questionnaires and focus group interviews for large Soldier populations based upon study team input; 2) to provide initial analyses of the questionnaire responses and focus group interviews, with additional, more-thorough, analyses as needed; and 3) to advance the state-of-the-art in survey development and administration within TRAC by developing an overarching methodology, developing supporting tools, and demonstrating unique analysis techniques.

The survey development team was able to integrate a wide range of stakeholder input for the creation of holistic and high-quality survey instruments. The team followed survey best-practices by garnering extensive stakeholder input, piloting the questionnaires, and avoiding common analysis pitfalls. Additionally, the team developed unique survey techniques to include developing a question submittal worksheet, conducting pattern analysis to reduce data entry errors, and conducting unique analyses of the data. Application of these unique techniques on such a large scale provided a significant contribution to the overarching study results.²⁴

There was one student thesis in support of this project. It is described in the following paragraph.

Applied Human Systems Integration: Developing a Methodology for the DOTMLPF Assessment of the Army's Land Warrior Soldier System, Petra Alfred, Department of the Army civilian:

The U.S. Armed Forces, through the Department of Defense (DoD) Directive 5000.1 and DoD Instruction 5000.2, requires optimizing total system performance and minimizing the cost of ownership through a "total system approach" to acquisition management (Defense Acquisition University, 2004). Human systems integration, an emerging interdisciplinary field, seeks to achieve optimal system performance by taking a human-centered perspective and approach to the system design and development process. DOTMLPF is a problem solving and assessment framework that includes Doctrine, Organization, Training, Leadership and Education, Materiel, Personnel, and Facilities and in some respects, is similar to HSI. This thesis examined the link between HSI and DOTMLPF as well as the relationships within the DOTMLPF areas and the HSI domains. In addition, since

²⁴ Eric Tollefson, Jonathan Alt, and Jeffrey Schamburg, *Questionnaire and Interview Development for Soldier System Analysis*, TRAC-MTRY Technical Memorandum, TRAC-M-TM-08-003. (Monterey, CA: TRAC-MTRY, TBP).

*a methodology did not yet exist for collecting DOTMLPF and HSI data, a survey methodology was identified, selected, developed, implemented, and applied to a real world case study--the DOTMLPF Assessment of the Army's Land Warrior (LW) System. Finally, this thesis uses the Land Warrior DOTMLPF survey effort and results from the Basis of Issue section of the survey as a case study to illustrate the utility of survey methodology for future DOTMLPF and HSI assessments, and to identify statistical techniques to analyze such data.*²⁵

2.2.8. Chemical, Biological, Radiological, and Nuclear Tactical Situation Awareness, FY07

The purpose of this research, sponsored by the Air Force Research Lab (AFRL), was to explore the impact of varying levels of situation awareness of chemical, biological, radiological, and nuclear (CBRN) agents on the operational effectiveness of mobile ground forces and evaluate the feasibility and utility of representing CBRN agents within the agent based model Pythagoras. This work additionally developed a methodology and tools to reduce the time required to construct scenarios within Pythagoras and to facilitate the use of large exploratory designs of experiments in high performance computing clusters. Finally, the work examined measures of performance and effectiveness for use in evaluating situational awareness of CBRN agents in mobile ground forces.

This effort resulted in tools and methodologies to facilitate the rapid generation of mobile force scenarios in a chemical environment. The research also produced a design of experiments tool to facilitate the broad exploration of factors of interest within these developed simulation scenarios in a high performance computing environment. A case study was completed using the developed methodology to examine the distribution of chemical sensors within a dismounted infantry platoon. Finally, an initial background review was conducted and candidate measures of performance (MOP) and measures of effectiveness (MOE) were developed to address the situational awareness related issues more accurately in constructive simulation.

There was one thesis done in support of the individual M&S aspects of this project. His thesis is described briefly below.

The Effects of Situation Awareness on Infantry in an Urban, Chemical Environment,
Walter Kent, III, US Army, TRAC-MTRY member as Second Reader:

Trends toward increased use of chemical weapons by enemies of the U.S. heighten the need for analysis of chemical situation awareness (SA) on the battlefield. To enhance the warfighter's ability to understand the effects of

²⁵ Petra Alfred, *Applied Human Systems Integration: Developing a Methodology for the DOTMLPF Assessment of the Army's Land Warrior Soldier System*, Masters Thesis (Monterey, CA: Naval Postgraduate School, 2007).

*chemical, biological, radiological, and nuclear (CBRN) weapons, the Air Force Research Laboratory (AFRL) is part of a team developing the Joint Operational Effects Federation (JOEF) decision support system. One area JOEF developers require further research is in the assessment of CBRN information requirements during mobile force operations in an urban, chemical environment. This thesis tests the capabilities of the agent-based simulation Pythagoras to model chemical environments and their effects on a dismounted, future force, infantry platoon. Research goals include assessing an agent-based simulation's ability to rapidly model a chemical environment, assessing levels of chemical SA and its impact on combat effectiveness, and developing mobile force use cases for further study by AFRL. The researcher utilized a Nearly Orthogonal Latin Hypercube design to examine 10 variables in 7,800 simulated engagements. Major findings show that Pythagoras supports chemical modeling and commanders should consider the likelihood of increased kinetic casualties while wearing chemical protective gear. Additionally, combat effectiveness improves when the joint chemical agent detector (JCAD) approaches instantaneous detection levels and unmanned ground vehicles (UGVs) possess JCAD.*²⁶

2.2.9. Modeling Close Range, Quick Reaction Engagements, FY06

The purpose of this research, sponsored by the Soldier FACT, was to identify the critical factors in close range quick reaction dismounted infantry engagements and to develop the knowledge, data and algorithms required to represent these engagements within constructive simulation. This area was identified by the Soldier FACT as an FY06 critical research area. These types of engagements have yet to be fully explored and are not well understood or represented. Yet these engagements occur throughout the current operating environment. This work was important because it should ultimately impact acquisition decisions for future equipment once incorporated into the Army's models and simulations. These decisions potentially impact every Soldier in the force.

To examine the issues for analysis, we developed a methodology from a knowledge, data and algorithms paradigm. The first portion of the effort sought to develop the background knowledge of the problem space and determine where gaps in the knowledge of these types of engagement existed. This resulted in a list of critical factors based on subject matter expert opinion and a detailed functional analysis.

Next, we examined available data on these types of engagements and determined what data was available to fill the critical factor requirements identified during the knowledge acquisition step. Data development events were executed to gain an initial level of knowledge to

²⁶ Walter Kent, III, *The Effects of Situation Awareness on Infantry in an Urban, Chemical Environment*, Masters Thesis (Monterey, CA: Naval Postgraduate School, 2007).

allow the development of algorithms to represent Soldier in these types of engagements. These data development events consisted of a post-combat questionnaire executed in conjunction with surveys conducted by the Directorate of Combat Developments (DCD) at the US Army Infantry Center (USAIC) and a live-virtual experiment executed in conjunction with the SBL, USAIC. In both cases, the events were designed to gain insight into Soldier behaviors in these close-range, quick-reaction engagements.

Finally, models were developed to represent Soldier performance and behavior in these types of engagements from existing and developed data. A conceptual modeling framework and proof of principle reference model incorporating the results of the research were developed as a path forward for future work and transfer into Army models and simulations, with an initial target of IWARS and a secondary target of the Combined Analysis Tool for the XXIst Century (COMBAT^{XXI}) simulation model.²⁷

2.2.10. Individual Soldier Close Combat Skills and Activities, FY06

The purpose of this joint research effort with AMSAA, sponsored by the Soldier FACT, was three-fold: 1) to provide expertise in the development of the experimental design, by defining the objectives of the experiment and assisting in designing the experiment to achieve those objectives; 2) to provide descriptive statistical analyses of the resulting experimental data; and 3) to produce algorithms from the data collected for representing probability of hit and time of engagement for such engagements.

This work established a partnership with AMSAA that leveraged the expertise of both agencies for the benefit of the Soldier. TRAC-MTRY's input into the experimental design for the live experimentation allowed the data to be more meaningful in terms of algorithm development. AMSAA superbly executed its plan and provided the data to TRAC-MTRY in a timely manner and in a useable format. TRAC-MTRY provided the specific descriptive statistics requested on the various tasks and also further analyzed the data, producing useful algorithms for

²⁷ Jonathan Alt, Christopher Darken, Michael Martin, Eric Tollefson, and Sergio Posadas, *Modeling Close Range Quick Reaction Engagements*, TRAC-MTRY Technical Report, TRAC-M-TR-055 (Monterey, CA: TRAC-MTRY, TBP)

kneeling and crouching firing positions for probability of hit and mean time of engagement for stationary targets fifty meters or less in daylight conditions.²⁸

2.2.11. *Integrated Soldier Situational Awareness / Search & Target Acquisition Modeling, FY08*

The purpose of this ongoing study (as of this writing) is to close the gap between Soldier M&S analysis needs for the interrelated concepts of Soldier situational awareness (SA) and search and target acquisition (STA).

Our objectives are threefold. The first objective is to identify and evaluate Soldier SA and STA representation within current models and simulations. This often-overlooked step is a critical start point for any work proposing to improve M&S. As part of this objective, we will examine the current state-of-the-art to identify shortcomings (thus focusing our efforts on improvements and minimizing duplication of effort) and to ensure that any proposed improvements are implementable within current simulation constructs.

The second objective is to develop an understanding of Soldier SA and STA and identify the interrelationships between Soldier SA and STA. This step will involve extensive data collection for both SA and STA. Data collection planning will be based upon the Distributed Model of Situated Cognition (DMSC), a model used to understand situational awareness. Additionally, we will capture how Soldiers change their search patterns and techniques based upon their SA. For instance, Soldiers may focus their attention on suspected enemy locations, areas of recent enemy activity, or away from areas already being scanned/searched by other friendly elements. Any or all of these elements of information may be available via SA and will affect his search patterns and techniques. What is available to the Soldier, and how it affects his behaviors (including more than just STA behaviors), is central to this effort. This effort will consider the identification of Soldier behaviors resulting from SA (e.g., cues, communications, common operating picture, etc) including efforts to gain additional required information, actions which are intrinsic to the purpose of search and target acquisition, as well as other behaviors.

The third objective is to develop algorithms and implementations in simulation to represent Soldier SA and its impacts on STA, with focus on IWARS, OOS, and COMBAT^{XXI}.

²⁸ Jonathan Alt, Eric Tollefson, Darryl Ahner, Michael Martin, Leroy Jackson, and Jeffrey Schamburg, *Individual Soldier Close Quarter Combat Skills and Activities*, TRAC-MTRY Technical Report (Monterey, CA: TRAC-MTRY, TBP).

Section 3 – Soldier Focus Area Collaboration Team (FACT) Support

At the beginning of this project, we actively participated in the Soldier MAWG by providing input and expertise into the processes of evaluating current Soldier M&S gaps. Upon the completion of the Soldier MAWG effort and its transition to the Soldier FACT, we remained actively involved in the new organization. TRAC-MTRY served on the FACT's Executive Committee (EXCOM). In that role, we made recommendations for future critical research areas (CRA), participated in the research proposal process by recommending synopses for white papers and evaluating the resulting proposals, and conducted other supporting actions as appropriate. Our submissions for recommended CRA for FY07 are shown in Appendix A and our recommended CRA for FY08 are shown in Appendix B. Additionally, we submitted proposals of our own to the process, two of which were selected for funding in FY06 and one in FY08. All three are discussed in the preceding section.

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Section 4 – Collaborative Web Portal Development

4.1. Requirements Definition

In October, 2005, we traveled to Fort Benning to brief leaders within the US Army Infantry Center (USAIC) on TRAC-MTRY capabilities and the work currently being done by, or in conjunction with, TRAC-MTRY in infantry Soldier M&S. We also went to request access to information regarding infantry developments across the DOTMLPF domains. Briefing recipients included leaders from the Office of Infantry Proponency, TRADOC Systems Manager (TSM) Soldier, Combined Arms and Tactics Division, Directorate of Combat Developments, and the Soldier Battle Lab. There was a very high level of interest in current M&S efforts and ensuring that there is an open exchange of information between the infantry and M&S communities. The result of these meetings was the idea to develop a Soldier M&S web portal as a centralized line of communication between stakeholders.

Our primary effort for this aspect of our research was to act as a link between NPS faculty and students and the US Army Infantry Center (USAIC), model developers, and researchers. As part of that, we planned to develop a collaborative web portal to communicate current Soldier M&S needs and developments among all stakeholders. Initially, we would design that web portal to describe the NPS and TRAC-MTRY research relating to the infantry Soldier. Subsequently, we hoped to expand the scope to include the larger Soldier M&S community. The web portal was not intended to be a repository for data (like Natick's Data Access and Retrieval Tool – DART), models (like the Modeling and Simulation Resource Repository – MSRR), or study reports (like the Defense Technical Information Center – DTIC). It was not intended to duplicate efforts.

Based upon our stakeholder analysis, we began to develop requirements for the web portal so that it would be designed to exchange information between Soldier M&S practitioners and the larger infantry community. We also made contact with the Soldier FACT chair to coordinate efforts regarding the relationship between a Soldier M&S web portal and a Soldier FACT website.

We defined the web portal's purpose as follows: to provide lines of communication between consumers and developers of infantry (individual combatant) models, simulation, and data by summarizing current research efforts, challenges, and requests for information. As already mentioned, it was not intended to be a repository of data, models, or study reports, as

such websites already exist. We will briefly describe the web portal requirements in the following paragraphs.

Infantry Modeling and Simulation Research and Efforts. This section would summarize infantry M&S efforts of interest to the community. Thus, entries must be directly related to infantry Soldier M&S, requiring some judgment on the part of site administrators to ensure the scope of the web portal does not get too broad. Also critical is that the descriptions of current efforts be written in a way that is understandable to all audiences, given the wide variety of personnel likely to access the site. We wanted to ensure that the general descriptions of research are not too academic or technical in nature. This section would ask submitting agencies to supply the following concerning their research:

- Title.
- Short description of their research (size-limited field for a very brief summary).
- Detailed description of their research (provides additional detail beyond that contained in the short description).
- Keywords to facilitate searches.
- Category(ies) into which the research can be grouped.
- Classification of the work (although the web portal itself would remain unclassified).
- Timeline for the effort (current progress, status, and future work).
- Issues/challenges/information that the submitting agency would like to pose the overall community.
- Contact information of the primary point of contact (POC).
- Links to further information.

Infantry Modeling and Simulation Needs. This section would summarize the M&S needs of the infantry community and would be a means through which members of the infantry community can submit priority topics of interest. The entries in this section must directly relate to infantry issues and must be written in a way that is understandable to all audiences. This section would ask submitting agencies to supply the following concerning their research needs:

- Topic.
- Short description of their research needs (size-limited field for a very brief summary).
- Contact information of the primary point of contact (POC).
- Detailed description of their research needs (provides additional detail beyond that contained in the short description).

- Links to further information.

Other Features. In addition to the above information, the web portal should have a discussion forum to allow stakeholder interaction on a variety of topics. We also planned to have aspects of the web portal password-protected so that submitters could have control over their own information in order to facilitate updates. Password protection would also prevent unauthorized information from being disclosed in a public forum, in accordance with current Information Assurance (IA) regulations. Such unauthorized information would include contact information that reveals names, phone numbers, agency, and other related information. Additionally, we planned to have a method to remind submitters to update their information every three or six months. Outdated information would be removed or archived. Finally, we planned to have links to other areas of interest to the infantry M&S community.

The original requirements document that we developed is shown in Appendix C. Those requirements continued to change throughout the development process.

4.2. Web Portal Development

After defining the requirements for the web portal, we researched the appropriate IA regulations to ensure that our web portal conformed to Department of Defense (DOD) and Department of the Army (DA) standards. In order to facilitate that, we decided to use the Army Knowledge Online (AKO) Single Sign-On (SSO) authentication service for user accounts. Unfortunately, due to various challenges, we were not able to implement that service in the timeframe demanded by our supporting web development contract. However, we tried to implement an alternate plan to ensure that Privacy Act information was still protected by not displaying contact information to users and using third-party electronic mail (email) techniques to facilitate communication between users, masking their identity. Once contact is established using this method, users would have the option to reveal contact information directly to the user who generated the email.

The prototype web portal that we developed allows M&S researchers and developers to provide summary information concerning their efforts and to associate their research and development efforts with particular M&S domains (analysis, experimentation, training, etc.), M&S categories (simulation, data, knowledge acquisition, studies, etc.), and Soldier domain categories (light infantry, airborne infantry, air assault infantry, mechanized infantry, special operations, etc.). Based upon that information, web portal users can search to find information

of interest. Similar information can also be entered by M&S consumers, with a focus on their needs and requirements.

As of the conclusion of this project, the web portal was not ready for launch. Due to the steep learning curve involved in developing such a portal, and our limited resources, we were unable to complete all of the required functionality. Particularly, we were not able to finish the third-party email functionality, which is critical for protecting user identity. Additionally, we were not able to set up the discussion forums. Nonetheless, the current prototype serves as a proof-of-concept and can be further developed into a working web portal. We will continue to share our work with other agencies with the desire of finding an appropriate host and additional funding for it.

Section 5 – Conclusions

We were very successful in getting the support of numerous students and faculty during the conduct of this three-and-half-year effort. In fact, during this timeframe, we attracted or shared the research of 24 students in two NPS Departments, at least seven NPS Ph.D. faculty members, 12 theses and dissertations for which TRAC-MTRY served as second readers or dissertation advisors/committee members, and at least ten other theses related to Soldier M&S. Students represented the US Army, US Navy, US Marine Corps, Singapore, Germany, and government civilians. Additionally, students and faculty used at least six existing simulation models, including Map Aware Non-uniform Automata (MANA), Pythagoras, the Infantry Warrior Simulation (IWARS), the Combined Analysis Tool for the XXIst Century (COMBAT^{XXI}), PAX, and the Recognition Primed Decision Model, as well as two simulations developed specifically by students for their research.

We were also very successful in our efforts to develop TRAC-MTRY projects in support of Soldier M&S. We developed two projects in support of the FFW Advanced Technology Demonstration (ATD); one project in support of the Land Warrior (LW) program; a project in support of AFRL's chemical, biological, radiological, nuclear (CBRN) tactical situational awareness efforts; and three projects as part of the Soldier FACT process.

We supported the Soldier MAWG by providing input and expertise into the processes of evaluating current Soldier modeling and simulation (M&S) capability gaps. Upon the completion of the Soldier MAWG effort and its transition to the Soldier FACT, we remained actively involved in the new organization, by serving on the FACT's Executive Committee (EXCOM). In that role, we made recommendations for future critical research areas (CRAs), participated in the research proposal process by recommending synopses for white papers and evaluating the resulting proposals, and conducted other supporting actions as appropriate. Additionally, we submitted proposals of our own to the process, two of which were selected for funding in FY06 and one in FY08.

We developed a prototype collaborative web portal to facilitate communication between Soldier M&S researchers and developers and Soldier M&S consumers that provides summaries of ongoing efforts and requirements. The web portal is not ready for launch, but is a viable proof-of-concept for future efforts.

Although the formal portion of this project is complete, we will continue to encourage faculty and students to work on Soldier M&S related topics. Since we have developed significant TRAC-MTRY expertise in Soldier M&S and will continue to pursue such topics in our research program, we will require the continued support of NPS students and faculty for the success of our projects. The relationships that we have already established through this project will ensure success in that regard.

Additionally, we will continue to serve on the Executive Committee of the Soldier FACT, and plan to remain involved in that process as it transitions to the new concept currently under development.

Finally, we will try to generate interest in and find a sponsor/host for the Soldier M&S web portal. We are still considering other options to establish an interim Soldier M&S collaborative web portal until a more complete solution can be implemented. Such interim prototypes may involve open-source solutions, such as phpBB™ and/or Wikimedia, that require low overhead and allow us to achieve a portion of our objectives.

Appendix A - TRAC-MTRY Recommended FY07 Soldier FACT CRAs

Recommended Critical Research Areas (CRAs): These are TRAC-MTRY's 3 recommended and 3 backup CRAs selected from the longer list below (including our rationale).

Table A-1. Recommended CRAs for FY07.

Priority	CRA Description	Rationale
1	Develop algorithms and data to represent the effects of suppression.	The modeling of suppression is critical to represent standard engagement phenomena, such as a support-by-fire position.
2	Develop algorithms and data to model human factors effects adequately, including physical and cognitive resources and fatigue impacts due to Soldier load and continuous operations on Soldier and small unit performance of critical individual tasks.	One of the primary aspects that makes a Soldier unique from other battlefield systems is the 'human' element. This must be modeled to determine even simplified effects due to Soldier load, terrain, etc. We should be taking steps now to understand these phenomena.
3	Develop algorithms and data to represent Soldier acquisition based upon cues, such as muzzle flash, smoke, auditory, shared situational awareness and knowledge about the environment (bunkers, windows, etc).	Standard search algorithms (ACQUIRE) do not account for a large number of critical factors that affect target acquisition.
Backup	Develop algorithms and data to represent the ability of individual Soldiers and small units to navigate and move from one location to another.	Current models cannot be used to demonstrate the value of GPS and other SA navigational tools without this capability.
Backup	Develop algorithms and data to represent how much cover and/or concealment is provided by a number of typical physical objects (to include vehicles) and how Soldiers utilize it.	Another aspect that makes Soldier M&S unique is the importance of microterrain on survivability. This needs to be modeled in some way to model engagements accurately.
Backup	Develop data for critical weapon/sensor pairings.	Studies cannot be executed without this information.

Critical Areas. The following are the areas that we believe are most important for CRA consideration from the prioritized list of Soldier modeling capability gaps in Appendix B of the Soldier Modeling and Analysis Group (MAWG) report. Our assessment is based upon importance to studies, ability to impact in a one-year timeframe, and whether they can or should be addressed by other FACTs or other avenues. They are grouped by phenomenon category.

Table A-2. Most Important Capability Gaps for FY07.

Phenomenon Category	Phenomenon	MAWG Priority	Gap Description
Lethality	Firing Decision and Engagement Process	1	A validated methodology is needed to represent Soldier acquisition, decision, and engagement of cues that provide information about the location of suspected Threat entities.
		4	A valid methodology or set of behavior rules by which the Soldier decides his highest priority target from a set of acquired targets is needed.
		22	A methodology and data are needed to represent a Soldier's ability to direct the fire of one or more other Soldiers using standard fire control techniques such as tracers, smoke, and laser pointers.
	Suppression	21	A study of the phenomenon of suppression, a methodology, and data are needed in order to credibly represent the effects of suppression.
Lethality (Continued)	Target Acquisition	Medium	There exists questions about the validity of the ACQUIRE model at short range (less than 200 meters). This includes multiple data voids.
		5	Methodologies representing how the dismounted Soldier acquires other dismounted persons in various environments (day, night, weather), changing light and shadows, changing optical contrasts, and uniforms are needed.
		13	A validated methodology that represents how the dismounted Soldier is cued to acquire other entities based on such events as muzzle flash, smoke, and auditory cues in various environments (day, night, weather) is needed.
	Target Acquisition and Weapons Effects	17	Acquisition data is needed to allow entities to acquire or be cued to bunkers, fighting positions, and other structures so that they can be engaged. Data is also needed to represent the effects of munitions against bunkers, fighting positions, and other fortified structures.
	Weapons Effects	Low	A methodology and data are needed in some models to represent the effects of direct fire munition fly-by the intended target.
		8	Numerous data voids exist for critical weapon/sensor pairings.
Mobility	Movement Techniques	Low	There is a need to collect data pertaining to individual combatant movement rates over various types of terrain and under various operational environments.
		Low	There is no standard library of Soldier behaviors that represent individual and small unit movement under fire.
	Navigation	Medium	There is a need to study the phenomenon of navigation, identify methodologies, and collect appropriate data to represent the ability of individual Soldiers and small units to move from one location to another.
	Soldier's Load	Medium	There is a need to better understand and represent other elements of the Soldier's performance that are affected by fatigue caused by the Soldier's load beyond the Soldier's speed.
Modeling the Physical Environment	Cover and Concealment	14	There is need to identify data on how much cover and/or concealment is provided by a number of typical physical objects (to include vehicles) and validate the probabilities of finding cover and concealment for each terrain type.
	Weather and Lighting	Medium	A methodology is needed for most models to represent the effects of shadowed areas on acquisition and movement decisions.
SA/C3I	SA	3	There is a need to better understand how individuals and small units behave given information that is available to them and translate that knowledge into validated behavior rules and decision tables.
	SA	10	For nonvirtual, HITL models, there is a need to present battlefield information to the interactor in a more robust way. The information needs to be able to be degraded such that the interactor does not have a too true representation of the battlefield ground truth.
Soldier Equipment Trust-worthiness	Equipment Reliability and Repair	Low	Methodologies and data are needed in order to represent equipment reliability and repair and degraded performance given an equipment failure.
Survivability & Protection	Human Factors	Medium	There is a need to develop data on how well Soldiers and units can perform a number of critical individual tasks.
	Human	18	Methods and data are needed in order to adequately model human factors

	Factors		effects. This gap includes physical and cognitive resources and fatigue impacts on Soldier and small unit performance of critical individual tasks.
	Injuries and Wounding	Low	A study of the phenomenon, a methodology, and data are needed in order to represent the blunt trauma damage to the Soldier caused by a nonpenetrating projectile strike on the Soldier's body armor.

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Appendix B - TRAC-MTRY Recommended FY08 Soldier FACT CRAs

Recommended Critical Research Areas (CRAs): These are TRAC-MTRY's 3 recommended CRAs selected from the longer list below (including our rationale).

Table B-1. Recommended CRAs for FY08.

Priority	CRA Description	Rationale
1	Develop algorithms, methodologies, and data to model human factors effects adequately, including physical and cognitive resources and fatigue impacts due to Soldier load and continuous operations on Soldier and small unit performance of critical individual and collective tasks.	One of the primary aspects that makes a Soldier unique from other battlefield systems is the 'human' element. This must be modeled to determine even simplified effects due to Soldier load, terrain, etc. We should be taking steps now to understand these phenomena.
2	Develop knowledge, algorithms, and data to model situational awareness and understanding and how individuals and small units behave given information that is available to them.	Understanding SA and how Soldiers react to the information provided is becoming increasingly important as Soldier systems of systems are being developed and linked to the tactical network.
3	Develop algorithms, methodologies, and data representing how the dismounted Soldier acquires other dismounted persons in various environments (day, night, weather), changing light and shadows, changing optical contrasts, and uniforms are needed, especially distinguishing civilians from enemy.	This is both operationally relevant in the current operating environment and relevant in terms of the Future Force. Additionally, this is still not well represented.

Critical Areas. The following are the areas that we believe are most important for CRA consideration from the prioritized list of Soldier modeling capability gaps in Appendix B of the Soldier Modeling and Analysis Group (MAWG) report. Our assessment is based upon importance to studies, ability to impact in a one-year timeframe, and whether they can or should be addressed by other FACTs or other avenues. They are grouped by phenomenon category.

Table B-2. Most Important Capability Gaps for FY08.

Phenomenon Category	Phenomenon	MAWG Priority	Gap Description
Lethality	Firing Decision and Engagement Process	1	A validated methodology is needed to represent Soldier acquisition, decision, and engagement of cues that provide information about the location of suspected Threat entities.
		4	A valid methodology or set of behavior rules by which the Soldier decides his highest priority target from a set of acquired targets is needed.
		22	A methodology and data are needed to represent a Soldier's ability to direct the fire of one or more other Soldiers using standard fire control techniques such as tracers, smoke, and laser pointers.
	Suppression	21	A study of the phenomenon of suppression, a methodology, and data are

			needed in order to credibly represent the effects of suppression.
Lethality (Continued)	Target Acquisition	Medium	There exists questions about the validity of the ACQUIRE model at short range (less than 200 meters). This includes multiple data voids.
		5	Methodologies representing how the dismounted Soldier acquires other dismounted persons in various environments (day, night, weather), changing light and shadows, changing optical contrasts, and uniforms are needed.
		13	A validated methodology that represents how the dismounted Soldier is cued to acquire other entities based on such events as muzzle flash, smoke, and auditory cues in various environments (day, night, weather) is needed.
	Target Acquisition and Weapons Effects	17	Acquisition data is needed to allow entities to acquire or be cued to bunkers, fighting positions, and other structures so that they can be engaged. Data is also needed to represent the effects of munitions against bunkers, fighting positions, and other fortified structures.
	Weapons Effects	Low	A methodology and data are needed in some models to represent the effects of direct fire munition fly-by the intended target.
		8	Numerous data voids exist for critical weapon/sensor pairings.
Mobility	Movement Techniques	Low	There is a need to collect data pertaining to individual combatant movement rates over various types of terrain and under various operational environments.
		Low	There is no standard library of Soldier behaviors that represent individual and small unit movement under fire.
	Navigation	Medium	There is a need to study the phenomenon of navigation, identify methodologies, and collect appropriate data to represent the ability of individual Soldiers and small units to move from one location to another.
	Soldier's Load	Medium	There is a need to better understand and represent other elements of the Soldier's performance that are affected by fatigue caused by the Soldier's load beyond the Soldier's speed.
Modeling the Physical Environment	Cover and Concealment	14	There is need to identify data on how much cover and/or concealment is provided by a number of typical physical objects (to include vehicles) and validate the probabilities of finding cover and concealment for each terrain type.
	Weather and Lighting	Medium	A methodology is needed for most models to represent the effects of shadowed areas on acquisition and movement decisions.
SA/C3I	SA	3	There is a need to better understand how individuals and small units behave given information that is available to them and translate that knowledge into validated behavior rules and decision tables.
	SA	10	For nonvirtual, HITL models, there is a need to present battlefield information to the interactor in a more robust way. The information needs to be able to be degraded such that the interactor does not have a too true representation of the battlefield ground truth.
Soldier Equipment Trust-worthiness	Equipment Reliability and Repair	Low	Methodologies and data are needed in order to represent equipment reliability and repair and degraded performance given an equipment failure.
Survivability & Protection	Human Factors	Medium	There is a need to develop data on how well Soldiers and units can perform a number of critical individual tasks.
	Human Factors	18	Methods and data are needed in order to adequately model human factors effects. This gap includes physical and cognitive resources and fatigue impacts on Soldier and small unit performance of critical individual tasks.
	Injuries and Wounding	Low	A study of the phenomenon, a methodology, and data are needed in order to represent the blunt trauma damage to the Soldier caused by a nonpenetrating projectile strike on the Soldier's body armor.

Appendix C - Original Collaborative Web Portal Requirements

Purpose: To provide lines of communication between consumers and developers of infantry (individual combatant) models, simulation, and data by summarizing current research efforts, challenges, and requests for information.

Requirements

1. Short description of intent.
2. Warning to disable pop-up blocker to use links.
3. Design.
 - 3.1. Intuitive.
 - 3.2. Multiple methods to get to the same information.
 - 3.3. Professional appearance.
4. Infantry Modeling and Simulation Research and Efforts.
 - 4.1. Written to be understandable to all audiences.
 - 4.2. Must be directly related to infantry issues.
 - 4.3. Titles.
 - 4.3.1. Text field.
 - 4.3.2. Understandable (not academic-speak).
 - 4.3.3. Less than xxx words (characters?).
 - 4.4. Short Description.
 - 4.4.1. Text Field.
 - 4.4.2. Understandable (not academic-speak).
 - 4.4.3. Less than xxx words (characters?).
 - 4.5. Taxonomy.
 - 4.5.1. Keyword entry for search database.
 - 4.5.1.1. Text field, semi-colon separated.
 - 4.5.2. Categories.
 - 4.5.2.1. Drop-down menu.
 - 4.5.2.2. Text field if “Other” is selected from the drop-down menu.
 - 4.5.2.3. Primary, secondary, tertiary.
 - 4.6. Access to Information.
 - 4.6.1. Sensitivity of the information (FUOU, classification, proprietary, etc).
 - 4.6.1.1. Drop-down list.
 - 4.6.1.2. Default – unclassified.
 - 4.6.1.3. Short description.
 - 4.6.1.3.1. Text Field.
 - 4.6.1.3.2. Less than xxx words/characters.
 - 4.6.2. Special access instructions.
 - 4.7. POC Information.
 - 4.7.1. Text.
 - 4.7.2. Name and title.
 - 4.7.3. Organization.
 - 4.7.4. Phone number.
 - 4.7.4.1. Controlled field (10-digit).
 - 4.7.4.2. Overseas?

- 4.7.5. DSN prefix, if applicable.
 - 4.7.5.1. Controlled field (3-digit).
 - 4.7.5.2. Overseas?
- 4.7.6. Fax number (optional).
 - 4.7.6.1. Controlled field (3-digit).
 - 4.7.6.2. Overseas?
- 4.7.7. Email address.
 - 4.7.7.1. Calls email program.
- 4.8. Current Progress / Status.
 - 4.8.1. Text Field.
 - 4.8.2. Description of where you are in the work.
 - 4.8.2.1. What's been done.
 - 4.8.2.2. What the next steps are.
 - 4.8.3. Understandable (not academic-speak); can possibly be more technical.
 - 4.8.4. Less than xxx words (characters?).
- 4.9. Current Issues.
 - 4.9.1. Text Field.
 - 4.9.2. Description of:
 - 4.9.2.1. Any issues you may have.
 - 4.9.2.2. Information that you're seeking (data, methodology).
 - 4.9.2.3. Related work that may be of assistance.
 - 4.9.3. Understandable (not academic-speak); can possibly be more technical.
 - 4.9.4. Less than xxx words (characters?).
- 4.10. Links to further information.
 - 4.10.1. Text Field.
 - 4.10.2. Directly calls web portal in a separate window.
 - 4.10.3. Disclaimer statement/page.
- 4.11. Document attachments (presentations, reports, etc).
 - 4.11.1. Size limitation.
 - 4.11.2. Calls document in a separate window.
- 5. Infantry Modeling and Simulation Needs.
 - 5.1. Written to be understandable to all audiences.
 - 5.2. Must be directly related to infantry issues.
 - 5.3. Topic.
 - 5.3.1. Text field.
 - 5.3.2. Understandable (not academic-speak).
 - 5.3.3. Less than xxx words (characters?).
 - 5.4. Short Description.
 - 5.4.1. Text field.
 - 5.4.2. Understandable (not academic-speak).
 - 5.4.3. Less than xxx words (characters?).
 - 5.5. POC Information.
 - 5.5.1. Text field.
 - 5.5.2. Name and title.
 - 5.5.3. Organization.
 - 5.5.4. Phone number.

- 5.5.4.1. Controlled field (10-digit).
 - 5.5.4.2. Overseas?
 - 5.5.5. DSN prefix, if applicable.
 - 5.5.5.1. Controlled field (3-digit).
 - 5.5.5.2. Overseas?
 - 5.5.6. Fax number (optional).
 - 5.5.6.1. Controlled field (3-digit).
 - 5.5.6.2. Overseas?
 - 5.5.7. Email address.
 - 5.5.7.1. Calls email program.
- 5.6. Detailed description.
 - 5.6.1. Text field.
 - 5.6.2. Understandable.
 - 5.6.3. Less than xxx words (characters?).
- 5.7. Links to further information.
 - 5.7.1. Disclaimer statement.
- 5.8. Document attachments (presentations, reports, etc).
 - 5.8.1. Size limitation.
- 6. Discussion forum.
 - 6.1. Separable by topic.
 - 6.2. Allows continuous threads of discussion.
- 7. Database.
 - 7.1. All descriptions must be unclassified (non-FOUO as well).
 - 7.2. Entered via webpage.
 - 7.3. Searchable.
 - 7.3.1. Keywords only, or entire text?
 - 7.3.2. Start with research vs needs.
 - 7.4. Password controlled.
 - 7.4.1. AKO.
 - 7.4.2. If above, how do non-military agencies get access.
 - 7.4.3. Protection.
 - 7.4.3.1. Viewable vs entry.
 - 7.4.3.2. By section or area.
 - 7.5. Hit counter.
 - 7.6. Interface.
 - 7.6.1. Easy to use.
 - 7.6.2. Form.
 - 7.7. Actually loaded onto web portal only after approval.
 - 7.8. Once approved, user has ability to update.
 - 7.8.1. Notification to webmaster of any updated information.
 - 7.9. Ability to enter multiple entries with the same POC information without having to reenter the info every time.
- 8. Links.
 - 8.1. Must have DoD disclaimer if moving to a non-DoD address.
 - 8.2. Editable only by the webmaster.
 - 8.3. Open as a separate pop-up window?

- 8.3.1. If so, must have warning to disable pop-up blockers.
- 8.4. Databases
 - 8.4.1. DART.
 - 8.4.2. CALL.
 - 8.4.3. Other.
- 8.5. Research Links
 - 8.5.1. All M&S source agencies (including service academies and military grad schools).
 - 8.5.2. Academic groups (non-military).
 - 8.5.3. Soldier links (e.g., Fort Benning, etc).

Appendix D - List of References

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Appendix E - Initial Distribution List

1. US Army Training and Doctrine Command Analysis Center
PO Box 8695
Monterey, CA 93943-0692
2. US Army Training and Doctrine Command Analysis Center
255 Sedgwick Avenue
Fort Leavenworth, KS 66027-2345
3. US Army Training and Doctrine Command Analysis Center
Martin Luther King Drive
White Sands Missile Range, NM 88002-5502
4. US Army Materiel Systems Analysis Activity
ATTN: AMSRD-AMS-CS
392 Hopkins Rd.
Aberdeen Proving Grounds, MD 21005-5071
5. US Army Natick Soldier Center
ATTN: AMSSB-RSS-MA(N)
Natick, MA 01760-5020
6. Defense Technical Information Center
ATTN: DTIC-O
8725 John J. Kingman Rd, Suite 0944
Ft. Belvoir, VA 22060-5422
7. Dudley Knox Library
Naval Postgraduate School
Monterey, CA 93943

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Glossary

ABS	Agent-Based Simulation
AFRL	Air Force Research Labs
AKO	Army Knowledge Online
AMSAA	Army Materiel Systems Analysis Activity
AMSO	Army Model and Simulation Office
ARTEP	Army Training and Evaluation Program
ATD	Advanced Technology Demonstration
BCSE	Battle Command, Simulation and Experimentation
CALL	Center for Army Lessons Learned
CBRN	Chemical, Biological, Radiological, Nuclear
COMBAT ^{XXI}	Combined Analysis Tool for the XXIst Century
CRA	Critical Research Area
CXXI	Combined Analysis Tool for the XXIst Century
DA	Department of the Army
DART	Data Access and Retrieval Tool
DCD	Directorate of Combat Developments
DMSC	Dynamic Model of Situated Cognition
DO	Distributed Operations
DOD	Department of Defense
DOTMLPF	Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, Facilities
DTIC	Defense Technical Information Center
EEA	Essential Element of Analysis
EXCOM	Executive Committee
FACT	Focus Area Collaborative Team
FFW	Future Force Warrior
GRADE	Geographical Recall and Analysis of Data in the Environment
HSI	Human Systems Integration
IA	Information Assurance
IBA	Interceptor Body Armor
IT	Information Technology

IWARS	Infantry Warrior Simulation
JCAD	Joint Chemical Agent Detector
JOEF	Joint Operational Effects Federation
LRAD	Long Range Acoustic Device
LW	Land Warrior
M&S	Modeling and Simulation
MANA	Map Aware Non-uniform Automata
MAS	Multi-Agent Simulations
MCWL	Marine Corps Warfighting Lab
MERS	Marine Expeditionary Rifle Squad
MEU	Marine Expeditionary Unit
MOE	Measure of Effectiveness
MOP	Measure of Performance
MOS	Military Occupational Specialty
MOVES	Modeling, Virtual Environments, and Simulation
MSRR	Modeling and Simulation Resource Repository
MW	Mounted Warrior
NLW	Non-Lethal Weapon
NPS	Naval Postgraduate School
PEO Soldier	Program Executive Office Soldier
PH	Probability of Hit
PK	Probability of Kill
PKO	Peace Keeping Operations
POC	Point of Contact
PSO	Peace Support Operations
SA	Situational Awareness
SaaS	Soldier as a System
SASO	Stability and Support Operations
SBL	Soldier Battle Lab
SCU	Small Combat Unit
S-MAWG	Soldier Modeling and Analysis Working Group
SSO	Single Sign-On
SUGV	Small Unmanned Ground Vehicle

TDY	Temporary Duty
TPO	Technology Program Office
TRAC MRO	TRAC Methods and Research Office
TRAC	TRADOC Analysis Center
TRAC-MTRY	TRAC in Monterey, CA
TRAC-WSMR	TRAC at White Sands Missile Range, NM
TRADOC	Training and Doctrine Command
TSM-Soldier	TRADOC Systems Manager - Soldier
TTP	Tactics, Techniques, and Procedures
UAV	Unmanned Aerial Vehicle
UGV	Unmanned Ground Vehicle
UO	Urban Operations
USAIC	US Army Infantry Center
USAIS	US Army Infantry School
XML	Extensible Markup Language

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